NMHDECAY 2.0: An updated program for sparticle masses, Higgs masses, couplings and decay widths in the NMSSM

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Abstract

We describe the the improved properties of the NMHDECAY program, that is designed to compute Higgs and sparticle masses and Higgs decay widths in the NMSSM. In the version 2.0, Higgs decays into squarks and sleptons are included, accompagnied by a calculation of the squark, gluino and slepton spectrum and tests against constraints from LEP and the Tevatron. Further radiative corrections are included in the Higgs mass calculation. A link to MicrOMEGAs allows to compute the dark matter relic density, and a rough (lowest order) calculation of BR($b \to s\gamma$) is performed. Finally, version 2.1 allows to integrate the RGEs for the soft terms up to the GUT scale.

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1 Introduction

The Next to Minimal Supersymmetric Standard Model (NMSSM) [1–9] provides a very elegant solution to the μ problem of the MSSM via the introduction of a singlet superfield $\widehat{S}$. For the simplest possible scale invariant form of the superpotential, the scalar component of $\widehat{S}$ acquires naturally a vacuum expectation value of the order of the SUSY breaking scale, giving rise to a value of μ of order the electroweak scale. Hence the NMSSM is the simplest supersymmetric extension of the standard model in which the fundamental Lagrangian contains just SUSY breaking terms but no other parameters of the order of the electroweak scale.

In addition, the NMSSM renders the "little fine tuning problem" of the MSSM, originating from the non-observation of a neutral CP-even Higgs boson at LEP II, less severe [2].

As in the MSSM, the phenomenology of the NMSSM depends on a certain number of parameters (mostly soft SUSY breaking parameters) that cannot be predicted from an underlying theory at present. It is then useful to have computer codes that compute physically relevant quantities as Higgs and sparticle masses, couplings, decay widths etc. as functions of the initial parameters in the Lagrangian. Such codes allow to investigate which regions in parameter space are in conflict with present constraints on physics beyond the standard model and, most importantly, which regions in parameter space can be tested in future experiments and/or astrophysical measurements.

In the MSSM, corresponding computer codes are HDECAY [10], FeynHiggs [11], Isajet [12], SoftSusy [13], MicrOMEGAs [14], Suspect [15], Spheno [16], CPSUPERH [17], SDECAY [18] and DARKSUSY [19]. In the NMSSM, the only available code at present is NMHDECAY [20].

In the present paper we describe the improvements performed in the version 2.0 of NMHDECAY. (In the meantime version 2.1 is available, whose features are described in the file README on the web page [20]. In the cases where they differ from the ones of version 2.0 they are described below.) First we recall the features of the previous version of NMHDECAY, version 1.1. Starting from a set of (low energy) parameters it performs the following tasks:

- It computes the masses and couplings of all physical states in the Higgs sector and in the chargino and neutralino sectors.

- It computes the branching ratios into two particle final states (quarks and leptons, all possible combinations of gauge and Higgs bosons, charginos, neutralinos, but not decays into squarks and sleptons) of all 6 Higgs particles of the NMSSM. Three body decays via WW^* and ZZ^* are computed as in HDECAY [10], but no four body decays are taken into account.

- It checks whether the Higgs masses and couplings violate any bounds from negative Higgs searches at LEP, including many quite unconventional channels that are relevant for the NMSSM Higgs sector. It also checks the bound on the invisible Z width (possibly violated for light neutralinos). In addition, NMHDECAY 1.1 checks the LEP bounds on the lightest chargino and on neutralino pair production.

- It checks whether the running Yukawa couplings λ, κ, h_t or h_b encounter a Landau singularity below the GUT scale.

- Finally, NMHDECAY 1.1 checks whether the physical minimum (with all vevs non-zero) of the scalar potential is deeper than the local unphysical minima with vanishing $\langle H_u \rangle$, $\langle H_d \rangle$ or $\langle S \rangle$.

The improvements in the versions 2.0+ are as follows:

1. Further radiative corrections are added in the Higgs sector, in order to improve the precision of the Higgs masses calculations. In addition, all squark and slepton masses (and mixing angles for the third generation) are computed.

2. Branching ratios of all Higgs states into squarks and sleptons are computed, and squark and slepton loops are included in the Higgs decays to two gluons and two photons.

3. Experimental constraints from LEP and Tevatron on squark, gluino and slepton masses are checked.

4. The dark matter relic density can be computed, via a call of a NMSSM version of MicrOMEGAs (that is provided on the same web site).

5. The branching ratio $BR(b \to s\gamma)$ is computed to lowest order.

6. In the version 2.1, the RGEs for the soft /susy/ breaking terms can be integrated up to M_{GUT}.

7. A Makefile for optimal compilation is provided.

The conventions concerning the Lagrangian of the model are the same as in version 1.1: The superpotential W is given by

$$W = h_t \widehat{Q} \cdot \widehat{H}_u \widehat{T}_R^c - h_b \widehat{Q} \cdot \widehat{H}_d \widehat{B}_R^c - h_\tau \widehat{L} \cdot \widehat{H}_d \widehat{L}_R^c + \lambda \widehat{S} \widehat{H}_u \cdot \widehat{H}_d + \frac{1}{3} \kappa \widehat{S}^3 \ . \tag{1.1}$$

(Hereafter, hatted capital letters denote superfields, and unhatted capital letters the corresponding (complex) scalar components.) The $SU(2)$ doublets are

$$\widehat{Q} = \left(\begin{array}{c} \widehat{T}_L \\ \widehat{B}_L \end{array} \right), \ \widehat{L} = \left(\begin{array}{c} \widehat{\nu}_{\tau L} \\ \widehat{\tau}_L \end{array} \right), \ \widehat{H}_u = \left(\begin{array}{c} \widehat{H}_u^+ \\ \widehat{H}_u^0 \end{array} \right), \ \widehat{H}_d = \left(\begin{array}{c} \widehat{H}_d^0 \\ \widehat{H}_d^- \end{array} \right). \tag{1.2}$$

Products of two $SU(2)$ doublets are defined as, e.g.,

$$\widehat{H}_u \cdot \widehat{H}_d = \widehat{H}_u^+ \widehat{H}_d^- - \widehat{H}_u^0 \widehat{H}_d^0 \ . \tag{1.3}$$

For the soft SUSY breaking terms we take

$$\begin{aligned} -\mathcal{L}_{\rm soft} \ &= m_{\rm H_u}^2 |H_u|^2 + m_{\rm H_d}^2 |H_d|^2 + m_{\rm S}^2 |S|^2 + m_Q^2 |Q^2| + m_T^2 |T_R^2| \\ &\quad + m_B^2 |B_R^2| + m_L^2 |L^2| + m_\tau^2 |L_R^2| \\ &\quad + (h_t A_t \ Q \cdot H_u T_R^c - h_b A_b \ Q \cdot H_d B_R^c - h_\tau A_\tau \ L \cdot H_d L_R^c \\ &\quad + \lambda A_\lambda \ H_u \cdot H_d S + \tfrac{1}{3} \kappa A_\kappa \ S^3 + \text{h.c.}) \, . \end{aligned} \tag{1.4}$$

The resulting mass matrices and couplings can be found in the appendix of ref. [20]. The conventions are also listed within the FORTRAN code as comments at the beginning of each corresponding subroutine.

The input parameters relevant for the Higgs sector of the NMSSM (at tree level) are

$$\lambda, \ \kappa, \ A_\lambda, \ A_\kappa, \ \tan\!\beta \ = \ \langle H_u \rangle \, / \, \langle H_d \rangle \, , \ \mu_{\rm eff} = \lambda \, \langle S \rangle \ . \tag{1.5}$$

As in the case of version 1.1, it is possible to a) use input and output formats according to the SUSY Les Houches Accord (SLHA) conventions [21] (with, however, a modified switch (65 instead of 23) for $\mu_{\rm eff}$), b) use a privately defined input and output format (scan), that allows to scan over a user defined range of the input parameters (1.5).

In the next section, we describe the improvements of versions 2.0 and 2.1. Apart from the additional radiative corrections, we discuss the precise meaning (renormalization scale) of the input parameters. In section 3, we describe in detail how the different versions NMHDECAY can be installed, compiled, and linked to MicrOMEGAs. We conclude with a short outlook.

2 Improvements in NMHDECAY 2.0 and 2.1

2.1 Radiative corrections to the Higgs masses

Concerning radiative corrections induced by (s)top and (s)bottom loops, we adopt the same philosophy as in version 1.1: First we compute the running Yukawa couplings h_t, h_b and λ as well as the Higgs vevs (and tanβ) at the scale of the stop and sbottom masses, taking into account effects of order $h_{t/b}^2$ times potentially large logarithms. (The input parameters λ (and hence $\mu_{\rm eff}$), κ, A_λ, A_κ are defined at the scale M_Z^2, which we can identify with m_{top}^2 within the present approximation.) Then we add the one loop radiative corrections $\sim h_{t/b}^4$ to the effective potential, taking the full dependence on stop/sbottom masses and mixing angles into account. The advantage of performing this calculation at the scale of the stop/sbottom masses is that the remaining dominant two loop corrections $\sim h_{t/b}^6$, $\sim h_{t/b}^4 \alpha_s$ are relatively simple. These latter corrections include now also the dependence on h_b (in contrast to the version 1.1) in order to cover the large tanβ regime. Also, as in version 1.1, due to this procedure several non leading two loop effects (related to squark mass splittings and mixings) are automatically included, as in ref. [22] for the MSSM.

New in the version 2.0 are the corrections of the order $\sim g^2 h_{t/b}^2$ to the CP even Higgs boson masses (where g denotes the electroweak gauge couplings), induced by the stop/sbottom D term couplings, whose dependence on the stop/sbottom masses is computed beyond the leading logarithmic approximation.

Concerning the logarithmic one loop corrections of the order $\sim g^4$ (to the mass of the lighter doublet like CP even state), we distinguish now the masses of the different squarks/sleptons of the different generations (assuming the first two generations to be degenerate). New in the version 2.0 are the logarithmic one loop corrections to fourth order in the NMSSM specific Yukawa couplings λ and κ, that have only recently been computed in ref. [23].

Finally, in version 2.0 the corrections of the order $\sim g^2 h_{t/b}^2$ to the Higgs pole masses (from contributions $\sim h_{t/b}^2$ to the Higgs self energies as in ref. [24]) are included.

The dominant sources of uncertainty on the mass of the lighter doublet like neutral Higgs boson mass are thus non logarithmic contributions of the orders g^4, $g^2\lambda^2$, λ^4, $g^2\kappa^2$, κ^4 and $\lambda^2\kappa^2$, and two loop contributions beyond the dominant double logarithms $\sim h_{t/b}^6, h_{t/b}^4\alpha_s$.

2.2 Higgs decays

In addition to the Higgs decays considered in the version 1.1, the version 2.0 of NMHDECAY includes now the possible two body decays of all CP even, CP odd and charged Higgs bosons into all squarks and sleptons. Also, squark and slepton loop contributions to the radiatively induced decays of the CP even and CP odd Higgs bosons into two photons and two gluons are included.

The corresponding code is essentially as in HDECAY [10], but with the more complicated Higgs self couplings and mixings in the NMSSM. The leading logarithmic corrections from top and bottom quark loops to the Higgs self couplings are included, and the Higgs squark couplings are scaled up to a scale Q^2 corresponding to the squark masses which takes care of large logarithmic radiative corrections $\sim h_{t/b}^2 \ln(M_{Squark}^2/M_Z^2)$, neglecting terms $\sim h_{t/b}^2 \ln(M_{Higgs}^2/M_{Squark}^2)$.

2.3 Sparticle masses

The masses and mixing angles of the two charginos and five (in the NMSSM) neutralinos were already calculated in the version 1.1 of NMHDECAY in the subroutines CHARGINO and NEUTRALINO. In the actual version 2.1, one loop radiative corrections to the neutralino and chargino mass matrices are included as in section 4.2 in [24].

In the subroutine MSFERM in the version 2.0+, also the slepton masses are computed, and the squark mixing angles and pole masses are calculated including the one loop α_s corrections[§].

The subroutine GLUINO in the versions 2.0+ includes a computation of the gluino pole mass to the order α_s.

In the actual version 2.1 we assume that the input values of the soft SUSY breaking

[§]We thank S. Kraml for contributions to the corresponding codes

terms are given at a SUSY scale $Q^2 = (2M_Q^2 + M_U^2 + M_D^2)/4$, where M_Q, M_U and M_D are the running squark masses of the first two generations. If desired, this scale can also be set by the user.

Thus, in the versions 2.0+ of NMHDECAY the complete sparticle spectrum is computed. Already in the version 1.1, the masses of the two charginos and the masses and couplings to the Z boson of the five neutralinos were compared to LEP constraints from direct searches and constraints on the invisible Z width. Now, in addition, NMHDECAY tests the squark and gluino masses against constraints from the Tevatron [25] and LEP [26]. (The Tevatron constraints are those used by the LEPSUSY Working group [26].) As usual, NMHDECAY issues a warning in case where any of the present constraints is violated. NMHDECAY is thus quite unique in testing the complete Higgs and sparticle spectrum against constraints from accelerator experiments.

2.4 Dark matter relic density

The dark matter relic density in the NMSSM has recently been studied in ref. [27] (for previous investigations, see refs. [28]). For this purpose, NMHDECAY 1.1 was used to compute the Higgs and sparticle spectrum, which was then fed into a new version of MicrOMEGAs extended to the NMSSM. MicrOMEGAs calculates all the relevant cross-sections for the lightest neutralino annihilation and coannihilation. It then solves the density evolution equation numerically, without using the freeze-out approximation, and computes the relic density of the lightest neutralino.

In the version 2.0 of NMHDECAY, the dark matter relic density can be computed for any choice of input parameters, by setting a simple flag in the input file, through a link to this NMSSM version of MicrOMEGAs. The details on how this link has to be installed will be given in the next section.

In case the corresponding flag is on, the computed amount of dark matter is compared to constraints from WMAP [29] ($.0945 < \Omega h^2 < .1287$), and a warning is issued in case the result is too large or too small. (Clearly, a warning corresponding to a too small LSP relic density can be ignored, if one is ready to assume additional contributions to the dark matter.)

2.5 BR($b \to s\gamma$)

In the version 2.0 of NMHDECAY the branching ratio BR($b \to s\gamma$) is computed to lowest order in the subroutine BSG. Contributions from charged Higgs and chargino/squark loops are included, which are the same as in the MSSM. The theoretical error is about 6% for $\tan\beta \lesssim 3$, but increases rapidly with increasing $\tan\beta$. Hence the result is only a rough estimate for $\tan\beta \gtrsim 5$.

2.6 The RGEs

A new feature of version 2.1 is the (possible) evolution of all NMSSM parameters up to the GUT scale. Three different subroutines are present:

- the subroutine RGES integrates the RGEs for the gauge and Yukawa couplings up to the GUT scale (defined by the matching of the $U(1)_Y$ and $SU(2)$ gauge couplings g_1 and g_2). It is always called and serves to compute M_{GUT} as well as the Yukawa couplings at the GUT scale in order to check the absence of a Landau singularity (by requiring any Yukawa coupling to be less than 4π). Two loop β functions are used, and the conversion from the $\overline{MS}$ to the $\overline{DR}$ scheme as well as all possible threshold effects between M_Z and the SUSY scale are taken into account.

- the subroutine RGESOFT integrates the RGEs for the couplings and the soft terms up to the GUT scale (that is now known from a previous call of RGES). This subroutine is always called in the version SLHA, but in the version SCAN it is called only if the output format "long" is chosen. (It is not useful, but time consuming, for large scans.) At present, terms $\sim \lambda^2$, κ^2 in the two loop coefficients of the β functions for the soft terms are missing (this will be improved in the near future).

- the subroutine RGESOFTINV integrates the RGEs for the couplings and the soft terms from the GUT scale down to the SUSY scale Q. It is called only if RGESOFT is called. Unless modified, it uses the outputs of the subroutines RGES and RGESOFT for the values of all parameters at the GUT scale and leads thus to no new results for the parameters at the SUSY scale. Unless modified, it produces no output and acts just as a dummy. However, the user can easily modify the values of the (or some) parameters at the GUT scale (by choosing INGUT=1, after which the subroutine has to be re-compiled), and generate an output for the resulting parameters at the

SUSY scale. These can subsequently be used as input, and allow to generate sets of parameters that have desirable properties (as partial universality) at the GUT scale. Clearly, the Higgs masses squared at the SUSY scale cannot be put in directly, and can be modified only indirectly by varying other parameters like $\tan\beta$, $\mu_{\rm eff}$, λ, κ, A_λ or A_κ.

3 How to install NMHDECAY

Two versions of NMHDECAY are available:

1. nmhdecay_slha uses an input file and produces output files that are suitable generalizations of the SLHA conventions [21]. It is configured for studying the properties of one user-defined point in parameter space.

2. nmhdecay_scan employs privately defined input and output files. It allows to scan over parts of or all of the NMSSM parameters λ, κ, $\mu_{\rm eff} = \lambda \langle S \rangle$, $\tan\beta$, A_λ and A_κ.

Both programs are based on one single Fortran code (nmhdecay_slha.f or nmhdecay_scan.f) contained in the compressed directory NMHDECAY.tgz that can be downloaded from the web page http://www.th.u-psud.fr/NMHDECAY/nmhdecay.html.

The directory NMHDECAY contains also a Makefile as well as input files for both versions and test output files. Once the compressed tar file NMHDECAY.tgz is downloaded, one should type:

```
tar -zxvf NMHDECAY.tgz
cd NMHDECAY
./make
```

The command make will create 2 executable files, nmhdecay_slha and nmhdecay_scan. If one wishes to compile just one of them, it suffices to type `./make nmhdecay_slha` or `./make nmhdecay_scan`. Both codes need data files in order to check Higgs, sfermion and gluino mass bounds from LEP and Tevatron. These data files are contained in the compressed tar file EXPCON.tgz that can be downloaded from the same web page. To uncompress it, simply type

```
tar -zxvf EXPCON.tgz
```

which generates a directory EXPCON. By default in NMHDECAY, the path to the files containing the constraints is ../EXPCON so that the directory EXPCON should be located at the same place as the directory NMHDECAY. However, if one wishes to place it somewhere else, it is possible to define a corresponding environment variable EXPCON_PATH:

a) From a C-Shell, type
   `setenv EXPCON_PATH full_path_to_EXPCON`
   For a permanent setting add the same line to the file .cshrc.

b) From a Bash Shell, type
   `export EXPCON_PATH=full_path_to_EXPCON`
   For a permanent setting add the same line to the file .bashrc.

Finally, for those wishing to compute the dark matter relic density in the NMSSM, a version of MicrOMEGAs_1.3 extended to the NMSSM [27] is contained in the compressed tar file micromegas_1.3_nmssm.tgz, also available on our web page. In order to uncompress and to compile the C code omg.c and the MicrOMEGAs library, one should type:

```
tar -zxvf micromegas_1.3_nmssm.tgz
cd micromegas_1.3_nmssm
./micro_make omg.c
```

This will generate the executable file omg that can be called from NMHDECAY. It is possible to put the directory micromegas_1.3_nmssm wherever one wants, provided one defines the environment variable MICROMG_PATH as above. Otherwise micromegas_1.3_nmssm has to be put in the same directory that contains NMHDECAY and EXPCON (*ie* the default value for MICROMG_PATH is ../micromegas_1.3_nmssm). However, if one wants to move the directory micromegas_1.3_nmssm (and consequently change the variable MICROMG_PATH) after the MicrOMEGAs library has been compiled, one needs to recompile it. In order to do this, one has first to remove the generated files using the script clean (included in the directory micromegas_1.3_nmssm). The sequence of commands is then:

```
mv  micromegas_1.3_nmssm new_path
setenv MICROMG_PATH new_path (C_Shell)
  or
```

```
export MICROMG_PATH=new_path (Bash-Shell)
cd new_path
./clean
./micro_make omg.c
```

We now outline the particular features of the two versions of NMHDECAY.

3.1 NMHDECAY_SLHA

The program nmhdecay_slha uses the input file slhainp.dat, a version of which (slhainp.dat.test) is contained in the directory NMHDECAY. This sample file appears in Table 1 below. Several comments on its contents are in order:

a) BLOCK MODSEL contains the switch 3 (corresponding to the choice of the model) with value 1, as attributed to the NMSSM in ref. [21]. Any other choice would cause the program to stop. We have also added the switch 9 corresponding to a flag for the call to MicrOMEGAs: if the flag is set to 0, the relic density is not calculated (and MicrOMEGAs does not need to be compiled). If the flag is set to 1, nmhdecay_slha calls the executable file omg which returns the relic density of the lightest neutralino if it is the LSP.

b) BLOCK SMINPUTS contains important Standard Model parameters.

1. The first is the inverse electromagnetic coupling constant $\alpha_{\rm em}^{-1}$, now at the scale $Q = M_Z$ (in contrast to the version 1.1 where it was taken at the scale $Q = 0$).
2. Second, since Higgs vevs and couplings are defined in terms of M_Z, M_W and G_F, an on shell scheme is used implicitly, and the values of M_Z, M_W and G_F are required. M_Z, G_F (and $\alpha_s(M_Z)$) are defined in BLOCK SMINPUTS, whereas the numerical value of M_W is defined in the subroutine INITIALIZE. This subroutine assigns default values to *all* parameters and reads the files with the experimental constraints (contained in the directory EXPCON).
3. Third, as part of this block the running b quark mass $m_b(m_b)$, the top quark pole mass and m_τ are read in.
4. In addition, nmhdecay_slha needs the strange quark mass $m_s(\overline{MS})$ and the charmed quark (pole) mass (taken as 190 MeV (at Q = 1 GeV) and 1.42 GeV, respectively,

as in HDECAY [10]), as well as the CKM matrix elements V_{us}, V_{cb} and V_{ub}. The numerical values of these five parameters are defined in the subroutine INITIALIZE. (For convenience, they are printed out in the output file spectr.dat, see below.)

c) BLOCK MINPAR contains the optional switch 0 with the input value for the renormalization scale Q at which the squark and slepton masses, trilinear couplings and gaugino masses are defined. For Q = 0 (or no switch 0) this renormalization scale is computed internally from the average of the first generation squark masses. The switch 3 corresponds to the input value for tanβ.

d) BLOCK EXTPAR contains the SUSY and soft-SUSY-breaking parameters. An extention of the SLHA conventions is needed here. The new entries are:

61	for λ
62	for κ
63	for A_λ
64	for A_κ
65	for $\mu_{\mathrm{eff}} = \lambda \langle S \rangle$

Note that in NMHDECAY 1.0, the switch 23 (corresponding to the MSSM μ parameter) was used for μ_{eff}. Introducing a new switch for this parameter allows, in principle, non zero values for both μ and μ_{eff}, although such a scenario is not implemented in NMHDECAY (the main motivation for the NMSSM is to get rid of the MSSM μ parameter). A non zero value for μ in switch 23 is simply ignored.

The output files of nmhdecay_slha are spectr.dat, decay.dat and omega.dat. The directory NMHDECAY contains test versions of these files – spectr.dat.test (see Table 2 below), decay.dat.test and omega.dat.test – corresponding to the sample input file slhainp.dat. The content of spectr.dat is as follows:

a) BLOCK SPINFO is followed by warnings (switch 3) if any phenomenological constraint is violated. This segment of the output also displays error messages (switch 4) if any of the Higgs, squark or slepton states have a negative mass squared. No spectrum output is produced in this latter case.

b) BLOCK SMINPUTS contains a printout of the Standard Model input parameters. The numerical values for M_W, m_s, m_c, V_{us}, V_{cb} and V_{ub}, that have no SLHA numbers, also

appear in lines subsequent to # SMINPUTS Beyond SLHA.

c) BLOCK MINPAR is followed by a printout of the value of tanβ.

d) BLOCK EXTPAR displays a printout of the SUSY and soft-SUSY-breaking parameters.

e) BLOCK MASS contains the masses of all Higgs and sparticle states. There, one finds several essential NMSSM generalizations of the SLHA conventions. The new entries, with proposed PDG codes, are

45	for the third CP-even Higgs boson,
46	for the second CP-odd Higgs boson,
1000045	for the fifth neutralino.

f) BLOCK LOWEN contains observables relevant for precision experiments at low energy, at present only the computed value for BR($b \to s\gamma$) (switch 1).

g) The Higgs mixings in the CP-even sector follow BLOCK NMHMIX and those in the CP-odd sector follow BLOCK NMAMIX. Both segments are required in order to parameterize the mixing in the enlarged Higgs sector in the NMSSM. The meaning of the matrix elements S_{ij} (i, j = 1, 2, 3) and P_{ij} (i, j = 1, 2, 3) is as follows.

- According to the SLHA conventions the Higgs weak eigenstates H_u, H_d are denoted by H_2, H_1, respectively. (Inside the Fortran code the Higgs states H_u, H_d are denoted by H_1, H_2, which is of no relevance for the SLHA output.) Hence, for the purpose of the SLHA output, the CP-even Higgs states are numbered by $S_i^{weak} = (H_{dR}, H_{uR}, S_R)$ (R refers to the real component of the field). If h_i are the mass eigenstates (ordered in mass), the convention is $h_i = S_{ij} S_j^{weak}$.

- In the CP-odd sector the weak eigenstates are H_{uI}, H_{dI}, S_I (I for imaginary component). Again, for the purpose of the SLHA output (NEW according to SLHA2 [21]!), the CP-odd Higgs states are denoted by $H_{uI} = H_{2I}$, $H_{dI} = H_{1I}$ and $S_I = H_{3I}$. The mass eigenstates are a_i where a_1 is the Goldstone mode $\tilde{G}$, and the two physical states a_2, a_3 are ordered in mass. Then the elements of P_{ij} are defined as $a_i = P_{ij} H_{jI}$.

h) BLOCK STOPMIX, SBOTMIX and STAUMIX contain the mixing matrices of the stop squarks, sbottom squarks and stau sleptons respectively, as defined in the MSSM.

i) BLOCK NMNMIX is followed by a printout of the obvious generalization of the 4×4 MSSM neutralino mixing matrix to the 5×5 NMSSM neutralino mixing matrix (with real entries); BLOCK UMIX and BLOCK VMIX are followed by printouts of the U and V matrices as defined in the MSSM.

h) As indicated, the subsequent BLOCKs GAUGE, YU, YD, YE, L/K, AU, AD, AE, AL/AK and MSOFT contain the couplings and soft SUSY breaking terms at the SUSY breaking scale, and the following BLOCKs with suffix GUT the corresponding parameters at the GUT scale.

The output file decay.dat gives the decay widths of all Higgs states into two particles, using the SLHA conventions and the above generalizations of the PDG codes both for the decaying particle and the final state particles. BLOCK DCINFO gives informations about the decay package (NMHDECAY version 2.1).

The output file omega.dat contains the relic density of the lightest neutralino (if OMGFLAG=1). BLOCK RDINFO gives informations about the relic density package (MicrOMEGAs version 1.3). BLOCK RELDEN is then followed by switch 1 corresponding to the relic density Ωh^2 and switch 2 corresponding to a warning in case the relic density of dark matter could not be computed or is excluded by WMAP bounds.

3.2 NMHDECAY_SCAN

The program nmhdecay_scan uses the input file scaninp.dat, a version of which (scaninp.dat.test) is downloaded automatically with the Fortran code (see Table 3 below). In this input file, the following parameters must be specified:

- the total number of points to be scanned in parameter space;
- the output format flag is 0 for "short", corresponding to simple rows of numbers per allowed point in parameter space, and 1 for "long", as described below;

- the flag OMGFLAG (0 for no relic density computation, 1 for relic density computation using MicrOMEGAs);

- lower and upper limits for the NMSSM parameters λ, κ, tanβ, $\mu_{\rm eff}$, A_λ and A_κ;

- the soft squark and slepton masses, trilinear couplings and the gaugino masses over all of which no scan is performed.

The scan in parameter space uses a random number generator, such that all NMSSM parameters are randomly chosen point by point in the parameter space within the specified limits. The standard model parameters ($\alpha_s(M_Z)$, G_F, $\alpha_{\rm em}^{-1}$, the lepton masses m_τ and m_μ, the gauge boson masses M_Z and M_W, the quark pole masses m_s, m_c, and m_t, the running bottom quark mass $m_b(m_b)$ and the CKM matrix elements V_{us}, V_{cb} and V_{ub}) are specified in the subroutine INITIALIZE.

The output file containing the physical parameters is always called scanout.dat, regardless of the output format chosen. The numbers printed out for the output format 0 (recommended for scans over more than 10 points in parameter space) should be edited according to the user's needs (see the section of the program in the subroutine OUTPUT following the comment line The following output can be edited according to the user's needs). The output format 1 is easily readable and shows

- the NMSSM parameters for each point as used as input, at the SUSY breaking scale, and at the GUT scale;

- possible warnings in case any phenomenological constraint is violated, or error messages ("fatal" errors) in case any of the Higgs or sfermion states has a negative mass squared (in which case no additional output is produced);

- for each of the six Higgs states, their mass, their decomposition in the basis of interaction eigenstates (H_u, H_d, S), their reduced couplings to gauge bosons (CV), up type quarks (CU), down type quarks (CD), two gluons (CG) and two photons (CGA) (all relative to a standard model Higgs boson with the same mass), their branching ratios (where "Higgses" denote all possible two Higgs final states, and "sparticles" all possible two particle neutralino/chargino/sfermion final states), and their total width;

- the neutralino, chargino and gluino masses (all masses in GeV), as well as the neutralino composition in the basis $\psi^0 = (-i\lambda_1, -i\lambda_2, \psi_u^0, \psi_d^0, \psi_s)$;
- the pole masses and cosine of the mixing angle for the stop and sbottom states, as well as the pole masses of the squarks of the first two generations;
- the masses and cosine of the mixing angle for the stau states, as well as the mass of the tau sneutrino and the masses of the first two generation sleptons;
- the dark matter relic density (if OMGFLAG=1);
- the branching ratio BR($b \to s\gamma$).

The output file scanerr.dat shows how many of the points in parameter space have avoided fatal errors or violations of phenomenological constraints, and the range in the NMSSM parameter space over which points have passed all these tests.

Users who wish to call a subroutine as a function of the Higgs or sparticle properties (masses, mixing angles and other quantities computed during the course of the scan) should use the parameters and common blocks found in the subroutine OUTPUT. The comments at the beginning of the main program should allow easy identification of all the parameters, branching ratios, mixing angles and so forth that would be of potential interest for inputting into a user's subroutine.

4 Summary and outlook

The versions 2.0+ of NMHDECAY are both a calculator of the NMSSM Higgs and sparticle spectrum, and a Higgs decay package. A quite unique feature of NMHDECAY is the check of each point in parameter space against limits on Higgs bosons and sparticles from accelerator experiments (LEP and Tevatron), that would have been impossible without the help of numerous collegues participating in these experiments.

Apart from additional radiative corrections to the Higgs masses, the new features of the version 2.0 of NMHDECAY are the inclusion of Higgs decays into squarks and sleptons, the computation of the squark, gluino and slepton masses and mixings, the computation of the dark matter relic density and the branching ratio BR($b \to s\gamma$).

Whereas the computation of the dark matter relic density is quite reliable (as in the version 1.3 of MicrOMEGAs), the result for the branching ratio BR($b \to s\gamma$) has still to be interpreted with care, notably for larger ($\gtrsim 5$) values of $\tan\beta$.

It is clear that further improvements of NMHDECAY would be desirable: more higher order corrections to both the Higgs masses and decay widths would be welcome, with the aim to reach the present accuracy in the MSSM. (Tests of NMHDECAY in the MSSM limit $\lambda, \kappa \to 0$ with μ_{eff} fixed indicate, however, that the deviation of the mass of the lightest CP even Higgs boson w.r.t. corresponding MSSM calculations, for the same CP odd Higgs pole mass and sparticle spectra, is limited to about 3% and mostly much smaller.)

Informations on low energy precision observables are included only in the form of a rough calculation of BR($b \to s\gamma$), which should certainly be improved. Also the anomalous magnetic moment of the muon as well as $\Delta\rho$ should be computed.

We plan to treat these issues in the near future.

Finally, it would be useful to be able to choose (universal) soft SUSY breaking terms at a GUT scale as in a mSUGRA version of the NMSSM. A corresponding code NMSPEC is in preparation.

Acknowledgments

We thank P. Skands for comments on new SLHA and PDG particle codes, S. Kraml for helpful contributions to the squark, slepton and gluino sector, G. Belanger and A. Pukhov for help with the link to MicrOMEGAs, and M. Schumacher, S. Hesselbach and W. Porod for comments on the previous version of NMHDECAY.

```
#  INPUT FILE FOR NMHDECAY VERSION 2.1
#  BASED ON SUSY LES HOUCHES ACCORD II
BLOCK MODSEL
    3     1         # NMSSM PARTICLE CONTENT
    9     0         # FLAG FOR CALL OF MICROMEGAS (0=NO, 1=YES)
BLOCK SMINPUTS
     1     1.27920000E+02   # ALPHA_EM^-1(MZ)
     2     1.16639000E-05   # GF
     3     1.17200000E-01   # ALPHA_S(MZ)
     4     9.11870000E+01   # MZ
     5     4.21400000E+00   # MB(MB)
     6     1.75000000E+02   # MTOP (POLE MASS)
     7     1.77710000E+00   # MTAU
BLOCK MINPAR
     0     4.68008177E+02   # REN. SCALE
     3     3.00000000E+00   # TANBETA
BLOCK EXTPAR
     1     8.16527293E+01   # M1
     2     1.53892994E+02   # M2
     3     4.72879088E+02   # M3
    11    -3.96388267E+02   # ATOP
    12    -7.44522774E+02   # ABOT
    13    -3.22488355E+02   # ATAU
    65     3.53337956E+02   # MU AT MZ
    31     2.40063601E+02   # M_eL
    32     2.40063601E+02   # M_muL
    33     2.39934370E+02   # M_tauL
    34     2.13138181E+02   # M_eR
    35     2.13138181E+02   # M_muR
    36     2.12838756E+02   # M_tauR
    41     4.74810720E+02   # M_q1L
    42     4.74810720E+02   # M_q2L
    43     4.20057207E+02   # M_q3L
    44     4.61771920E+02   # M_uR
    45     4.61771920E+02   # M_cR
    46     3.36293030E+02   # M_tR
    47     4.60437692E+02   # M_dR
    48     4.60437692E+02   # M_sR
    49     4.60051305E+02   # M_bR
    61     2.00000000E-01   # LAMBDA AT MZ
    62     1.47434810E-01   # KAPPA AT MZ
    63    -7.50350192E+01   # A_LAMBDA AT MZ
    64    -2.18338774E+00   # A_KAPPA AT MZ
```

Table 1: Sample slhainp.dat file.

```
# NMHDECAY OUTPUT IN SLHA FORMAT
# Info about spectrum calculator
BLOCK SPINFO        # Program information
     1   NMHDECAY   # spectrum calculator
     2   2.1        # version number
# Input parameters
BLOCK MODSEL
    3     1         # NMSSM PARTICLE CONTENT
BLOCK SMINPUTS
     1     1.27920000E+02   # ALPHA_EM^-1(MZ)
     2     1.16639000E-05   # GF
     3     1.17200000E-01   # ALPHA_S(MZ)
     4     9.11870000E+01   # MZ
     5     4.21400000E+00   # MB(MB)
     6     1.75000000E+02   # MTOP (POLE MASS)
     7     1.77710000E+00   # MTAU
# SMINPUTS Beyond SLHA:
# MW:     0.80420000E+02
# MS:     0.19000000E+00
# MC:     0.14000000E+01
# VUS:     0.22000000E+00
# VCB:     0.40000000E-01
# VUB:     0.40000000E-02
BLOCK MINPAR
     3     3.00000000E+00   # TANBETA
BLOCK EXTPAR
     1     8.16527293E+01   # M1
     2     1.53892994E+02   # M2
     3     4.72879088E+02   # M3
    11    -3.96388267E+02   # ATOP
    12    -7.44522774E+02   # ABOTTOM
    13    -3.22488355E+02   # ATAU
    65     3.53337956E+02   # MU
    31     2.40063601E+02   # LEFT SELECTRON
    32     2.40063601E+02   # LEFT SMUON
    33     2.39934370E+02   # LEFT STAU
    34     2.13138181E+02   # RIGHT SELECTRON
    35     2.13138181E+02   # RIGHT SMUON
    36     2.12838756E+02   # RIGHT STAU
    41     4.74810720E+02   # LEFT 1ST GEN. SQUARKS
    42     4.74810720E+02   # LEFT 2ND GEN. SQUARKS
    43     4.20057207E+02   # LEFT 3RD GEN. SQUARKS
    44     4.61771920E+02   # RIGHT U-SQUARKS
    45     4.61771920E+02   # RIGHT C-SQUARKS
    46     3.36293030E+02   # RIGHT T-SQUARKS
    47     4.60437692E+02   # RIGHT D-SQUARKS
    48     4.60437692E+02   # RIGHT S-SQUARKS
    49     4.60051305E+02   # RIGHT B-SQUARKS
    61     2.00000000E-01   # LAMBDA
    62     1.47434810E-01   # KAPPA
    63    -7.50350192E+01   # A_LAMBDA
    64    -2.18338774E+00   # A_KAPPA
#
```

```
BLOCK MASS   # Mass spectrum
#  PDG Code     mass              particle
        25     9.74781199E+01   # lightest neutral scalar
        35     4.48583968E+02   # second neutral scalar
        45     5.16024735E+02   # third neutral scalar
        36     2.19434909E+01   # lightest pseudoscalar
        46     4.50932452E+02   # second pseudoscalar
        37     4.55175450E+02   # charged Higgs
   1000001     4.96428647E+02   #  ~d_L
   2000001     4.80320535E+02   #  ~d_R
   1000002     4.91385003E+02   #  ~u_L
   2000002     4.80115856E+02   #  ~u_R
   1000003     4.96428647E+02   #  ~s_L
   2000003     4.80320535E+02   #  ~s_R
   1000004     4.91385003E+02   #  ~c_L
   2000004     4.80115856E+02   #  ~c_R
   1000005     4.40278168E+02   #  ~b_1
   2000005     4.77873225E+02   #  ~b_2
   1000006     3.03200260E+02   #  ~t_1
   2000006     5.24782130E+02   #  ~t_2
   1000011     2.43747516E+02   #  ~e_L
   2000011     2.16456923E+02   #  ~e_R
   1000012     2.33286301E+02   #  ~nue_L
   1000013     2.43747516E+02   #  ~mu_L
   2000013     2.16456923E+02   #  ~mu_R
   1000014     2.33286301E+02   #  ~numu_L
   1000015     2.15119676E+02   #  ~tau_1
   2000015     2.44554112E+02   #  ~tau_2
   1000016     2.33153313E+02   #  ~nutau_L
   1000021     5.01506590E+02   #  ~g
   1000022     7.55014082E+01   # neutralino(1)
   1000023     1.38801726E+02   # neutralino(2)
   1000025    -3.58593816E+02   # neutralino(3)
   1000035     3.80957538E+02   # neutralino(4)
   1000045     5.24690943E+02   # neutralino(5)
   1000024     1.37945343E+02   # chargino(1)
   1000037     3.79628706E+02   # chargino(2)
# Low energy observables
BLOCK LOWEN
         1     3.33858054E+00   # BR(b -> s gamma)*10^4
# 3*3 Higgs mixing
BLOCK NMHMIX
  1  1    -3.33228276E-01   # S_(1,1)
  1  2    -9.41055786E-01   # S_(1,2)
  1  3     5.80768815E-02   # S_(1,3)
  2  1    -9.29046853E-01   # S_(2,1)
  2  2     3.17227652E-01   # S_(2,2)
  2  3    -1.90364284E-01   # S_(2,3)
  3  1    -1.60719818E-01   # S_(3,1)
  3  2     1.17390906E-01   # S_(3,2)
  3  3     9.79994140E-01   # S_(3,3)
```

```
# 3*3 Pseudoscalar Higgs mixing
BLOCK NMAMIX
  1  1     3.16227766E-01   # P_(1,1)
  1  2    -9.48683298E-01   # P_(1,2)
  1  3     0.00000000E+00   # P_(1,3)
  2  1    -9.84143132E-02   # P_(2,1)
  2  2    -3.28047711E-02   # P_(2,2)
  2  3    -9.94604680E-01   # P_(2,3)
  3  1     9.43564848E-01   # P_(3,1)
  3  2     3.14521616E-01   # P_(3,2)
  3  3    -1.03737795E-01   # P_(3,3)
# 3rd generation sfermion mixing
BLOCK STOPMIX  # Stop mixing matrix
  1  1     5.65184261E-01   # Rst_(1,1)
  1  2     8.24964697E-01   # Rst_(1,2)
  2  1    -8.24964697E-01   # Rst_(2,1)
  2  2     5.65184261E-01   # Rst_(2,2)
BLOCK SBOTMIX  # Sbottom mixing matrix
  1  1     9.94871315E-01   # Rsb_(1,1)
  1  2     1.01148731E-01   # Rsb_(1,2)
  2  1    -1.01148731E-01   # Rsb_(2,1)
  2  2     9.94871315E-01   # Rsb_(2,2)
BLOCK STAUMIX  # Stau mixing matrix
  1  1     1.82923365E-01   # Rsl_(1,1)
  1  2     9.83127175E-01   # Rsl_(1,2)
  2  1    -9.83127175E-01   # Rsl_(2,1)
  2  2     1.82923365E-01   # Rsl_(2,2)
# Gaugino-Higgsino mixing
BLOCK NMNMIX  # 5*5 Neutralino Mixing Matrix
  1  1     9.76939885E-01   # N_(1,1)
  1  2    -1.21822079E-01   # N_(1,2)
  1  3     1.55584479E-01   # N_(1,3)
  1  4    -8.03150977E-02   # N_(1,4)
  1  5     9.52878280E-03   # N_(1,5)
  2  1     1.69572219E-01   # N_(2,1)
  2  2     9.41177948E-01   # N_(2,2)
  2  3    -2.44926790E-01   # N_(2,3)
  2  4     1.58638593E-01   # N_(2,4)
  2  5    -1.65528778E-02   # N_(2,5)
  3  1    -4.43118962E-02   # N_(3,1)
  3  2     7.05108082E-02   # N_(3,2)
  3  3     6.98006382E-01   # N_(3,3)
  3  4     7.10367686E-01   # N_(3,4)
  3  5     3.50645553E-02   # N_(3,5)
  4  1    -1.21736484E-01   # N_(4,1)
  4  2     3.06778393E-01   # N_(4,2)
  4  3     6.47820106E-01   # N_(4,3)
  4  4    -6.79460614E-01   # N_(4,4)
  4  5     9.86388891E-02   # N_(4,5)
  5  1     7.09990264E-03   # N_(5,1)
  5  2    -1.60840169E-02   # N_(5,2)
  5  3    -9.44486010E-02   # N_(5,3)
  5  4     4.57635935E-02   # N_(5,4)
  5  5     9.94321905E-01   # N_(5,5)
```

```
BLOCK UMIX  # Chargino U Mixing Matrix
  1  1     9.25480029E-01   # U_(1,1)
  1  2    -3.78796404E-01   # U_(1,2)
  2  1     3.78796404E-01   # U_(2,1)
  2  2     9.25480029E-01   # U_(2,2)
BLOCK VMIX  # Chargino V Mixing Matrix
  1  1     9.69142290E-01   # V_(1,1)
  1  2    -2.46501971E-01   # V_(1,2)
  2  1     2.46501971E-01   # V_(2,1)
  2  2     9.69142290E-01   # V_(2,2)
#
# GAUGE AND YUKAWA COUPLINGS AT THE SUSY SCALE
BLOCK GAUGE Q=  4.68008177E+02 # (SUSY SCALE)
         1     3.60690129E-01   # g1(Q,DR_bar)
         2     6.45231920E-01   # g2(Q,DR_bar)
         3     1.10281535E+00   # g3(Q,DR_bar)
BLOCK YU Q=  4.68008177E+02 # (SUSY SCALE)
  3  3     9.40962309E-01   # HTOP(Q,DR_bar)
BLOCK YD Q=  4.68008177E+02 # (SUSY SCALE)
  3  3     4.53102195E-02   # HBOT(Q,DR_bar)
BLOCK YE Q=  4.68008177E+02 # (SUSY SCALE)
  3  3     3.17949988E-02   # HTAU(Q,DR_bar)
BLOCK L/K Q=  4.68008177E+02 # (SUSY SCALE)
         1     2.00784168E-01   # LAMBDA(Q,DR_bar)
         2     1.48000459E-01   # KAPPA(Q,DR_bar)
#
# SOFT TRILINEAR COUPLINGS AT THE SUSY SCALE
BLOCK AU Q=  4.68008177E+02 # (SUSY SCALE)
  3  3    -3.96388267E+02   # ATOP
BLOCK AD Q=  4.68008177E+02 # (SUSY SCALE)
  3  3    -7.44522774E+02   # ABOT
BLOCK AE Q=  4.68008177E+02 # (SUSY SCALE)
  3  3    -3.22488355E+02   # ATAU
BLOCK AL/AK Q=  4.68008177E+02 # (SUSY SCALE)
         1    -8.42676828E+01   # ALAMBDA
         2    -2.56530300E+00   # AKAPPA
#
# SOFT MASSES AT THE SUSY SCALE
BLOCK MSOFT Q=  4.68008177E+02 # (SUSY SCALE)
         1     8.16527293E+01   # M1
         2     1.53892994E+02   # M2
         3     4.72879088E+02   # M3
        21     5.81854464E+04   # M_HD^2
        22    -1.04142570E+05   # M_HU^2
        23    -1.32549686E+05   # M_S^2
        31     2.40063601E+02   # M_eL
        32     2.40063601E+02   # M_muL
        33     2.39934370E+02   # M_tauL
        34     2.13138181E+02   # M_eR
        35     2.13138181E+02   # M_muR
        36     2.12838756E+02   # M_tauR
        41     4.74810720E+02   # M_q1L
        42     4.74810720E+02   # M_q2L
        43     4.20057207E+02   # M_q3L
        44     4.61771920E+02   # M_uR
        45     4.61771920E+02   # M_cR
        46     3.36293030E+02   # M_tR
        47     4.60437692E+02   # M_dR
        48     4.60437692E+02   # M_sR
        49     4.60051305E+02   # M_bR
```

```
#  MU_EFF:   3.53749043E+02 # (AT THE SUSY SCALE)
#
# GAUGE AND YUKAWA COUPLINGS AT THE GUT SCALE
BLOCK GAUGEGUT MGUT=  2.39561249E+16 # (GUT SCALE)
         1     7.18934347E-01   # g1(MGUT,DR_bar), GUT normalization
         2     7.18934334E-01   # g2(MGUT,DR_bar)
         3     7.09148313E-01   # g3(MGUT,DR_bar)
BLOCK YUGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3     6.29869150E-01   # HTOP(MGUT,DR_bar)
BLOCK YDGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3     1.69658275E-02   # HBOT(MGUT,DR_bar)
BLOCK YEGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3     2.17473793E-02   # HTAU(MGUT,DR_bar)
BLOCK LGUT/KGUT MGUT=  2.39561249E+16 # (GUT SCALE)
         1     2.22229350E-01   # LAMBDA(MGUT,DR_bar)
         2     1.61430186E-01   # KAPPA(MGUT,DR_bar)
#
# SOFT TRILINEAR COUPLINGS AT THE GUT SCALE
BLOCK AUGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3    -2.00014623E+02   # ATOP
BLOCK ADGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3    -1.99980396E+02   # ABOT
BLOCK AEGUT MGUT=  2.39561249E+16 # (GUT SCALE)
  3  3    -1.99994867E+02   # ATAU
BLOCK ALGUT/AKGUT MGUT=  2.39561249E+16 # (GUT SCALE)
         1    -1.99976861E+02   # ALAMBDA
         2    -2.29490634E+01   # AKAPPA
#
# SOFT MASSES SQUARED AT THE GUT SCALE
BLOCK MSOFTGUT MGUT=  2.39561249E+16 # (GUT SCALE)
         1     2.00004409E+02   # M1
         2     2.00001910E+02   # M2
         3     1.99989075E+02   # M3
        21     3.99907796E+04   # M_HD
        22     4.00122196E+04   # M_HU
        23    -1.42907310E+05   # M_S
        31     3.99987978E+04   # M_eL
        32     3.99987978E+04   # M_muL
        33     3.99987958E+04   # M_tauL
        34     4.00004265E+04   # M_eR
        35     4.00004265E+04   # M_muR
        36     4.00004222E+04   # M_tauR
        41     3.99950362E+04   # M_q1L
        42     3.99950362E+04   # M_q2L
        43     3.99997864E+04   # M_q3L
        44     3.99948593E+04   # M_uR
        45     3.99948593E+04   # M_cR
        46     4.00046814E+04   # M_tR
        47     3.99956655E+04   # M_dR
        48     3.99956655E+04   # M_sR
        49     3.99956856E+04   # M_bR
```

Table 2: Corresponding spectr.dat.test output file.

```
#
#  Total number of points scanned
#
1
#
#  Output format 0=short 1=long (not recommended for big scannings)
#
1
#
#  Computation of relic density using MicrOmegas (0=no, 1=yes)
#
1
#
#  lambda
#
.2D0
.2D0
#
#  kappa
#
.147D0
.147D0
#
#  tan(beta)
#
3.D0
3.D0
#
#  mu
#
353.D0
353.D0
#
#  A_lambda
#
-75.D0
-75.D0
#
#  A_kappa
#
-2.2D0
-2.2D0
#
#  Remaining soft terms (no scan)
#
mQ3=  420.D0
mU3=  336.3D0
mD3=  460.D0
mL3=  240.D0
mE3=  213.D0
AU3=  -396.4D0
AD3=  -744.5D0
AE3=  -322.5D0
mQ=   474.8D0
mU=   461.8D0
mD=   460.4D0
mL=   240.D0
mE=   213.1D0
M1=   81.7D0
M2=   153.9D0
M3=   472.9D0
```

Table 3: The scaninp.dat file for sample parameter scan.

References

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